Circadian Biology: Sleep-Styles Shaped by Light-Styles

Light and darkness are the main time cues synchronising all biological clocks to the external environment. This little understood evolutionary phenomenon is called circadian entrainment. A new study illuminates our understanding of how modern light- and lifestyles compromise circadian entrainment and impact our biological clocks.

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Let there be light. For most of human history, light was solely available during the day [1], whereas now it is an on-demand commodity. Despite its many supporting effects in everyday life, recently it has become clear that the widespread — and often uncontrolled — application of artificial light creates significant problems [2]. Why is this the case and what are the problems? Light and darkness, naturally occurring by the alternation of day and night, are the major zeitgebers (time cues) for all biological clocks, also synchronising (entraining) most of our bodily rhythms and especially the times when we sleep to the external environment [2–4]. In this issue of *Current Biology*, Wright and colleagues [5] describe important findings that enlighten our understanding of natural entrainment and underscore the impact of artificial light on our circadian clocks and sleep. Notably, our heterogeneous genes and behaviourally-shaped, disparate environments create individual clocks that entrain with different phase positions relative to a zeitgeber (e.g., sunrise). These differences in entrainment create individual sleep windows and research has shown that sleeping within the biological sleep window is most efficient [6]. Individuals with different phases of entrainment are different chronotypes [7] and among the general population there is a near bell-shaped distribution from early sleepers and risers ('larks'), to late sleepers and risers ('owls') (Figure 1). Interestingly, by closing our eyes during sleep we manipulate the light input to our clock, which is why sleep by itself is central to the entrainment process by light [2]. In simple terms, the timing of our sleep window is tightly connected to the timing of our circadian clock: affecting the one also impacts the other!

Epidemiological studies show that average human sleep duration is decreasing worldwide and the increasing illumination of the globe penetrating our natural dark hours of sleep has been connected to this change in sleep timing [1]: light *will* change circadian entrainment and the consequence of this is altered timing of sleep. Although man-made light pollution is part of this story, one should not too quickly point fingers at Edison for his invention of the light bulb. In their current study, Wright and colleagues [5] show that not too much of light, but rather too little light across the 24-hour day challenges circadian entrainment. Wright *et al.* [5] assessed light exposure, sleep timing and the production of melatonin (a biomarker of the internal clock [8]) in a group of young and healthy participants. The authors compared the effects of artificial 'everyday' light levels to the effects of natural light levels on circadian entrainment. They found that modern artificial everyday light-styles lead to later entrainment with later sleep times and later melatonin production of about two hours, which was pronounced in later chronotypes. By subjecting their participants to one week of camping, free from light pollution and with

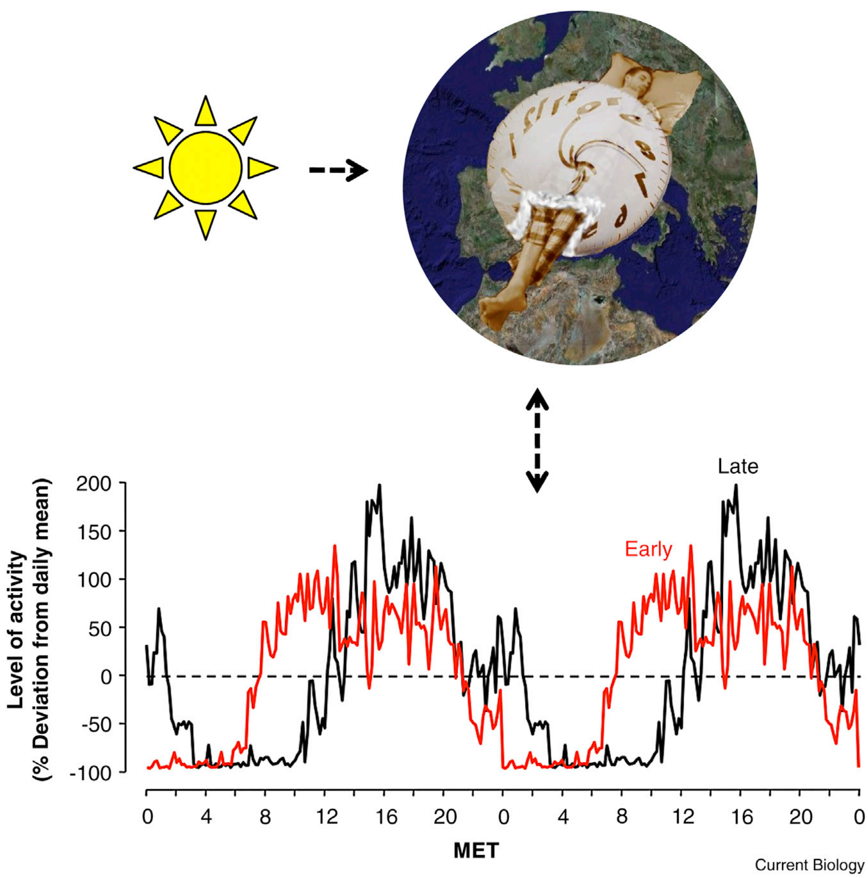

Figure 1. Light, the circadian clock, and behaviour.

Light entrains the internal circadian clock, sleep timing and leads to individual chronotypes with individual activity patterns, illustrated here for one 'Early' (red curve in lower panel) and one 'Late' chronotype (black curve in lower panel). MET; Middle European Time. (Redrawn from [10].)

more natural light during the day, the authors found that the onset and end of sleep in their participants entrained to the natural dawn and dusk. This effect, again, was strongest in later chronotypes.

Why is this finding important? As understood, entrainment is the key to getting sufficient sleep, to promote daytime alertness and longer-term health. This, for example, is supported by a host of shift-work studies showing that challenging entrainment significantly challenges sleep and health [9]. Recent research could even show that the biannual transition to and from daylight saving time significantly challenges circadian entrainment [10] and health [11]. Alarmingly, research [2] from the group of Till Roenneberg in Munich shows that 80% of the general population use alarm clocks on their workdays. That means that 80% of the general population relies on their 'ringing sleep bandits' cutting off their needed sleep in the morning, mostly to be at work on time. Consequently, lost sleep on workdays is compensated for on free days and weekends by considerably longer sleep episodes. The impressive figure of four-fifths of the population using an alarm clock to wake up on workdays also shows that most people sleep during different sleep windows on workdays and on free days and only rarely fulfil their biological sleep needs. The phenomenon of sleeping at different times on workdays and free days has been coined *social jetlag* [12] and it correlates positively with increased prevalence of smoking [12], obesity [13], depression [14], and cardiovascular problems [15]. Why don't we simply go to bed earlier to prevent this problem? Again, it is the circadian clock that dictates our individual sleep time in synchrony with zeitgeber input from the environment. Can chronobiology help? Circadian entrainment theory suggests that brighter light in the morning and dimmer light in the evening will shift sleep to earlier hours for most people, a finding that has also been shown experimentally [16,17]. These effects depend, in addition, on light history [18]. Furthermore, solely reducing light exposure in the evening hours was also shown to be beneficial to sleep quality [19]. These results are now supported and elaborated further in the study of Wright and colleagues [5]. Consequently, we now can better understand that weak entrainment resulting from inadequate light exposure during the day must be considered leading to increased vulnerability towards light pollution — especially in the evening hours — delaying our clocks and sleep windows. Notably, Wright and colleagues [5] also discuss how natural entrainment can contribute to improved brain arousal and cognitive performance at waking up, implying that entrainment improves the process of waking up — and our morning social skills probably as well.

What can we learn from these studies? First, humans — as with most animals — rely on regular light exposure to be entrained and to get sufficient sleep. Second, we learn that light pollution must be taken very seriously, as it significantly affects our circadian clocks that govern our sleep and everything else with a daily up and down. As stated earlier by Roenneberg *et al.* [2,20], it is the total 24-hour light exposure that is crucial to circadian entrainment, and not additive, fragmented light exposure over a day. Like other quantitative scientists, we have learned about chronobiology principles via many meticulously controlled laboratory studies in the past decades. But, verifying this knowledge under the 'noisy' conditions of 'real life' brings new insights and offers the unique opportunity to disclose new challenges to natural entrainment (e.g., the amplitude of light/dark cycles, the interaction between amplitude and varying amounts of light across the day, individual lifestyle choices, diet, etc.), which all by themselves inspire new research and provide astonishing outcomes. Field studies as the one published now by Wright *et al.* [5] are of utmost importance to further reveal natural entrainment, meaning entrainment that our clocks evolved to.

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